Bachelor's programme in Exercise Biomedicine, 180 credits

Aerobic endurance test for Table Tennis

A correlation study between Cooper’s test and Critical frequency test amongst Swedish-ranked players

Pontus Sparf

Exercise Biomedicine, 15 credits

Halmstad 2016-05-24
Aerobic endurance test for Table Tennis
A correlation study between Cooper’s test and Critical frequency test amongst Swedish-ranked players

Pontus Sparf

2016-05-24
Bachelor thesis 15 credits in Exercise Biomedicine
Halmstad University
School of Business and Engineering
Thesis supervisor: Emma Haglund
Thesis Examiner: Sofia Ryman Augustsson
Acknowledgment

I wish to thank my supervisor Emma Haglund and examiner Sofia Ryman Augustsson for their guidance and feedback during the process of writing this thesis. I also wish to thank Alessandro Zagatto for answering questions and providing some of his studies and James Parker for his assistance with equipment and procedures during testing. Finally, I am giving my thanks to the table tennis trainers and participants from Aspero Idrottsgymansium, Halmstad table tennis club and Scandinavian College of Sports through their participation, made this bachelor thesis possible.
Abstract

Background: Table tennis is a complex sport, which uses both aerobic and anaerobic endurance. Whereby the aerobic endurance system is mostly used during the rest periods in order to maintain active and fully focused under the intense periods which occurs during ball rallies. The Swedish Olympic committee provides with a physiological profile where the aerobic endurance of the table tennis players is tested with Cooper’s test. The Cooper’s test is not sport specific and thereby a sport specific aerobic endurance test was developed, since player performance should be measured precise and sport specific. The sport specific aerobic endurance test is named Critical frequency test and is performed with a mechanical ball thrower.

Aim: The purpose of this study was to evaluate the strength of the correlation between Cooper’s test and Critical frequency test with subjects national ranking. A second aim was to compare the strength of the correlation between Cooper’s test and Critical frequency test with subjects national ranking.

Method: 14 subjects participated in this correlation study. Their aerobic endurance was measured with a Cooper’s test performed on a treadmill where their time to complete 3000m in seconds was gathered and with two critical frequency tests performed at different intensities (48 respectively 56 balls/minute) where their time to exhaustion in seconds was gathered.

Results: A strong correlation was found between Cooper’s test and subjects group ranking, based on their national ranking ($r=0.600$ and $r^2=0.360$, $p=0.023$). A weak non-significant correlation was found between Critf test and subjects group ranking at 48 respectively 56 balls/minute (48: $r=-0.341$ and $r^2=0.116$, $p=0.233$) and (58: $r=0.022$ and $r^2=0.0005$, $p=0.940$).

Conclusion: The results in this study showed a strong correlation between Cooper’s test and subjects group ranking. This means, that in table tennis players ranked from 20-2700 in Sweden, the Cooper’s test could be used, in order to evaluate player performance. However, the Critf test could be questioned since a weak non-significant correlation was found. Future research is needed to evaluate the Critf test in this area, on a more homogenous group concerning the ranking list in Sweden.
Table of Contents

Background ........................................................................................................................................... 1
Table tennis as a sport .......................................................................................................................... 1
Physiologic aspects and physical demands in Table tennis ................................................................. 2
  Energy deficits ................................................................................................................................... 2
  Anaerobic system ............................................................................................................................... 2
  Aerobic system .................................................................................................................................. 2
  Usage of aerobic and anaerobic systems in TT .................................................................................. 3
Cooper’s test ......................................................................................................................................... 4
Sport specific tests in table tennis ......................................................................................................... 4
Ranking ................................................................................................................................................ 6

Aim ....................................................................................................................................................... 7
Research questions ................................................................................................................................ 7
Hypothesis ............................................................................................................................................. 7

Methods ............................................................................................................................................... 7
Study design .......................................................................................................................................... 7
Subjects ............................................................................................................................................... 8
Test sessions ........................................................................................................................................ 8
  Cooper’s test 3000m .......................................................................................................................... 9
  Critical frequency test ..................................................................................................................... 9
Ranking system .................................................................................................................................... 11
Statistical analysis ............................................................................................................................... 11
Ethical and social consideration .......................................................................................................... 11

Results ............................................................................................................................................... 12

Discussion .......................................................................................................................................... 15
Results discussion ............................................................................................................................... 15
  Cooper’s test .................................................................................................................................... 15
  Critf test .......................................................................................................................................... 16
Discussion of methods ......................................................................................................................... 17
  Participants ....................................................................................................................................... 17
  Cooper’s test .................................................................................................................................... 17
  Critf test .......................................................................................................................................... 18

Conclusion .......................................................................................................................................... 19

References .......................................................................................................................................... 20

Appendices ......................................................................................................................................... 23
  Appendix 1. Information form which was handed out to each subject ................................................. 23
  Appendix 2. Content form which was signed by each subject ............................................................ 25
Background

Table tennis as a sport

Table tennis (TT) is one of the fastest ball games played these days. It is a game where you as a player need to combine the skill of getting the ball over the net and reposition in order to hit the next shot when the ball comes back from your opponent (Kondrič, Zagatto, & Sekulić, 2013; Kondrič, Furjan-Mandić, Kondrić, & Gabaglio, 2010). The International Federation of Table Tennis (ITTF) changed some of the rules in 2000 (Li, Zhao, & Zhang, 2005). Rule changes were done regarding size of the ball (changed from 38mm to 40mm), the equipment; as making the rubber thicker and the glue was changed from non-water based glue to only allow water-based glue. A shorter point system, from 21 points per set to 11 points per set was also introduced. The rule changes have made the overall length of a TT match a bit longer than before, the difference is although not so big (Kondrič, Zagatto, & Sekulić, 2013; Kondrič, Furjan-Mandić, Kondrić, & Gabaglio, 2010). The rule changes influenced the game to become more equal for all players, regarding the glueing of material.

TT is a complex sport containing both aerobic and anaerobic skills. The players need to be highly endurance trained, in order to complete tournaments. When competing at world-class, the tournaments usually runs over a week, containing many matches and different classes, which demands an effective recovery. (Kondrič, Zagatto, & Sekulić, 2013; Kondrič, Furjan-Mandić, Kondrić, & Gabaglio, 2010). To get an idea of the players’ current physical capacity, there are different ways to evaluate. The physiological profile, is a test protocol for measuring maximum and explosive strength, aerobic endurance and sprint performance. The physiological profile, composed by the Swedish Olympic Committee, is used to decide who to fund for future training and competing in the current sport. There is a physiological profile for each Olympic sport, but the tests performed in the physiological profile is almost the same for each sport making it less sport specific. For measuring aerobic endurance, the physiological profile uses the Cooper’s test (Svenska Olympiska Kommittén, 2016). The Cooper’s test where the athlete runs as far as he or she can during 12 minutes (Cooper, 1970), is used in almost every Olympic sport for evaluating a players’ physiological capacity for examples in curling, table tennis, golf, figure skating but also many other sports (Svenska Olympiska Kommittén, 2016). Despite the fact that the Swedish Olympic Committee works with and for elite athletes competing in Olympic Sports, their way of testing athletes is similar in every sport. Usage of the same test protocol for sports of different kinds, could therefore be quesitonned.
Physiologic aspects and physical demands in Table tennis

Energy deficits

In every movement completed by a human being or any sort of life, there is an underlying source of energy converting in order to get the movement done. A human can extract the energy stored in macronutrients and transfer it to skeletal muscle, which can perform a movement (McArdle, Katch, & Katch, 2007, s.230). The main role in energy is Adenosine triphosphate (ATP), which gives us the possibility to transfer and store energy within the body (McArdle, Katch, & Katch, 2007, s.231). Two different energy systems could be used in order to extract energy; the aerobic energy system and the anaerobic energy system. Whereas the aerobic energy system uses oxygen when converting glycogen through glycolysis to ATP (McArdle, Katch, & Katch, 2007, s.168) and the anaerobic energy system uses stored ATP as primary energy source (McArdle, Katch, & Katch, 2007, s.140). TT demands a combination between both aerobic and anaerobic systems. The aerobic system is mostly used to recover the anaerobic system; which is used during ball rallies between players. A player’s ability to extract energy from the anaerobic system can sometimes be the difference between winning and loosing (Kondrič, Zagatto, & Sekulić, 2013; Kondrič, Furjan-Mandić, Kondrič, & Gabaglio, 2010).

Anaerobic system

TT is a sport with periods of intense effort, were the primarily used system during these periods is the immediate energy system. The immediate energy system, also know as, ATP;PCr system, which means that the energy comes from phosphagenic sources, such as, ATP and phosphocreatine (PCr) (McArdle, Katch, & Katch, 2007, s.231; Zagatto, Papoti, & Gobatto, 2008a; Zagatto, Papoti, & Gobatto, 2008b). The ATP;PCr system, has a stored energy which can be used for about 6-8 seconds, and is mainly from the intramuscular high-energy phosphates (McArdle, Katch, & Katch, 2007, s.231; Zagatto, Papoti, & Gobatto, 2008a). The human body has a limited storage capacity for ATP, each kilogram of skeletal muscles contains about 3-8mmol of ATP and approximately 4-5 times more PCr. (McArdle, Katch, & Katch, 2007, s.140).

Aerobic system

The aerobic energy system is also known as the long-term energy system. In the aerobic endurance system, the energy comes from glycolysis, the long-term energy system uses oxygen when converting glycogen to ATP. The amount of oxygen required when converting glycogen
to ATP depends on what type and intensity of the exercise. Glycolysis in this form provides with a relatively small amount of ATP but can do so for a very long time. This system is used when the exercise exceeds several minutes (McArdle, Katch, & Katch, 2007, s.168).

During aerobic work the amount of oxygen used by the muscles can be measured by quantifying the amount of ingoing and out coming oxygen through the lungs (McArdle, Katch, & Katch, 2007, s.168). In this way, you get a precise number on how much oxygen that was up taken within the muscles and the body, which equals to oxygen consumption during exercise. When the intensity of the work has a balance between energy consumption by the muscles and the ATP production in the aerobic metabolism it is defined as the steady state. The steady state generally describes the intensity where a person can perform the activity without getting tired (McArdle, Katch, & Katch, 2007, s.168).

Maximal oxygen consumption is the absolute maximum of oxygen which the muscles can use during exercise. When the muscles are incapable to consume enough oxygen in order to transport away lactate and convert glycogen to ATP a lactate accumulation occurs, this will lead to fatigue. Maximal oxygen consumption is described as VO$_2$max and measures a person’s ability to resynthesize ATP aerobically. VO$_2$max is expressed in milliliters of oxygen per kilogram of body mass per minute ($mL \ast kg^{-1} \ast min^{-1}$) (McArdle, Katch, & Katch, 2007, s.171). VO$_2$max tests are both timeconsuming and expensive to perform, they are also physically demanding for the subject who performs the test. Easier ways of validating a persons aerobic capacity is in form of submaximal tests i.e through Cooper’s test, were the VO$_2$max is estimated from a submaximal work.

**Usage of aerobic and anaerobic systems in TT**

In a review from Kondrič, Zagatto, & Sekulić (2013) two types of endurance is described and they are based on the aerobic and anaerobic systems. These two types of endurance are related to different moments in the game. The anaerobic is most associated with repeatedly hit powerful strokes and continuesly move rapidly over the court, in order to do this a combination between muscular strength and anaerobic development is used. The aerobic system is most associated with recovery of the anaerobic system and support players to stay focused and active during long competitions. When measuring physiological demands within table tennis players the interest is often more in measuring which performance level that can be maintained without
fatigue rather than how high the aerobic power is at the point of exhaustion (Kondrič, Zagatto, & Sekulić, 2013).

Cooper’s test
Dr. Kenneth Cooper invented the 12-minute run as a field test for estimating aerobic endurance, since testing in a laboratory were to expensive and time consuming. The goal is to travel as far as possible during 12 minutes. Then measure the distance covered and compare with a table describing fitness categories in relation to the covered distance. As they found some practical problem with the 12-minute run when testing a lot of people at the same time Cooper and colleagues invented the 1,5 miles run. In this test the subject run over 1,5 miles and the time is measured (Cooper, 1970).

According to Cooper (1970) the validity of his 12-minute run test were checked and determined with treadmill measurements of oxygen consumption and aerobic capacity. Their measurements between distance covered during a 12-minute run and the treadmill measurements of oxygen consumption and aerobic capacity showed a strong correlation (r=0.90).

The validity of Cooper’s test has also been checked by Bandyopadhyay (2015) in Indian male univeristy students. Bandyopadhyay tested the Cooper’s 12-minute run and compared the results with an incremental test on a stationary wattbike in eighty-eight students with an age of 22,8 ± 1,7 years. Bandyopahyay found a strong and significant correlation between measured VO$_{2\text{max}}$ and distance covered in the Cooper’s (r=0.93, p=<0,001) (Bandyopadhyay, 2015). Despite the fact that submaximal tests have showed a good validity when compared to VO$_{2\text{max}}$ tests, they still lack of the sportspecific component for TT players. In recent years, sportspecific aerobic and anaerobic tests have become more frequently used when validating players.

Sport specific tests in table tennis
Sport specific tests in TT have been hard to establish since it is a complex sport using a lot of skills. Sport specific TT test have been the lactate minimum test (Kondrič, Zagatto, & Sekulić, 2013), which is a test to determine the maximum lactate steady state (MLSS) (Macintosh, Esau, & Svedahl, 2002). This is a tests which are referred to as sport specific, even though it is a more general test. The lactate minimum test which Kondrič, Zagatto, & Sekulić (2013) are referring
to is performed both with a cycle ergometer and arm cranking, where the arm cranking is supposed to be the TT specific moment. Since TT players use their arms and therefore get tired in their arms, as well as their legs where the cycle ergometer is used to measure the fatigue in legs (Kondrič, Zagatto, & Sekulić, 2013). According to Kondrič, Zagatto, & Sekulić (2013) the lactate minimum test is not the most valued way of measuring intensity in racket sports, since it is important to measure endurance with precision, and in a more sport specific manner.

In a study by Zagatto, Papoti & Gobatto (2008a) they mention a test called critical power concept (critP) which was founded by Herve Monod and Jean-Jaques Scherrer in 1965. This test evaluates both aerobic and anaerobic parameters without a high cost. The test has two components, one that is measuring aerobic capacity called critical power (critP) and one which is measuring anaerobic capacity which is called anaerobic work capacity (AWC). The AWC is used at intensities greater than the critical power and represents the restricted supply of energy, which means that fatigue could be the result when a complete discharge of AWC has been accomplished. Zagatto, Papoti & Gobatto (2008a) used the model of critP and adapted it to a sport-specific test for table tennis players using a mechanical ball thrower and named it critical frequency test (Critf). Each test person did the test on 3 or 4 different speeds, 48, 56, 65 and 72 balls per minute. The test stopped when four consecutive errors were made or when the test person voluntarily stopped due to exhaustion (Zagatto, Miranda, & Gobatto, 2011).

The validity of the Critf test has been tested by Zagatto, Papoti, & Gobatto (2008b). They tested Critf test and compared it with two other tests, a MLSS test and an incremental test. Both the MLSS test and the incremental test was performed with the mechanical ball thrower. The MLSS test was performed on three different speeds (90% of Critf, 100% of Critf and 106% of Critf) and lasted for approximately 20 minutes at a constant work load. The blood samples were taken from the earlobe every four minutes. For the incremental test they had an initial frequency of 34 balls per minute and incremented the frequency of 5 balls per minute every 3 minutes until voluntary exhaustion. Blood samples was collected from the earlobe after each exercise stage. They found a strong correlation between Critf test and lactate minimum test ($r=0.78$, $p=0.03$), and also a strong correlation with the incremental test ($r=0.79$, $p=0.02$). A moderate correlation was found between Critf test and onset of blood lactate accumulation (OBLA) ($r=0.42$, $p=0.34$), however this correlation was non-significant and the sample size were small (Zagatto, Papoti, & Gobatto, 2008b). Taken together, the Critf test has been tested on a population of Brazilian male international TT players and have not been compared with subjects national ranking.
Ranking

There are other ways to estimate a TT player’s actual performance. One of them is through national and international ranking. Swedish table tennis association administrates a ranking system for players who compete, either at international, national or regional level. This ranking system is based on the world ranking system (Svenska Bordtennisförbundet, 2015, s.11-14). It is the same list for men as for women, so in fact men compete with women, even though they do not do this at a competition. Each player have thirty days to get points or lose points in order to move in the table. There is a different amount of points that each match is worth, depending on your placement in the ranking table and your opponents placement in the ranking table. The winner of the match is rewarded with the points the match was worth which is withdrawn from the loser’s points (Svenska Bordtennisförbundet, 2015, s.11-14).

Cooper’s test is frequently used by the Swedish Olympic Committee since it is an easy and low costing aerobic endurance test. TT is an Olympic sport, it is in the elite athletes and their trainers’ interest to know what skills they need to progress in order to make their way to the Olympics. With a sport specific endurance test, the trainers could check for deprivation of skills during the same test. Therefore it is in the trainers’ interest to check which of, the existing aerobic endurance test and the sport specific aerobic endurance test, that is most associated with players’ national ranking.
Aim

The aim of this study was to evaluate the strength of the correlation of the Cooper’s test and the more sport specific critical frequency test with the national ranking of table tennis players. A second aim was to compare the strength of the correlation between Cooper’s and Critf test with national ranking of table tennis players.

Research questions

1. Which is the strength of the correlation between Cooper’s test and the Swedish table tennis players national ranking?
2. Which is the strength of the correlation between Critf test and the Swedish table tennis players national ranking?
3. Which of the two tests, Cooper’s test or Critf test, is most associated with measuring aerobic endurance amongst Swedish table tennis players, in relation to national ranking?

Hypothesis

My hypothesis was that the Critf test would have a stronger correlation with national ranking than Cooper’s test.

Methods

Study design

This study is a cross-sectional study performed during 1:st of March until 31:th of April. All tests were performed in Halmstad Arena, the Critf tests were performed in the locale for table tennis and the Cooper’s test were performed at the gym (Actic). The same equipment was used for every test, with equipment means same treadmill (STARTRAC, E-TRx, Irvine, USA), table (STIGA Competition, Tranås, Sweden) and equal balls (STIGA Optimum, Tranås, Sweden). All tests for each subject was lead by the same test leader and the tests occurred at approximately the same time for each subject. In order to describe the group, their background information was collected in form of age, weight and length.
Subjects

Twenty-five subjects from Scandinavian College of Sports (SCoS), Aspero Idrottsgymnasium and Halmstad Table Tennis Club (HBTK), both men and women, were invited for participation in the study. The inclusion criterions were healthy TT players, in age 13-30 years old, who trains and compete in TT, placement better than 3000 at the ranking list from Swedish TT federation (SBF), without injuries affecting their participation during the last six months. The exclusion criterions were if the subject for some reason did not have a national ranking or had an injury within the last six months, which could affect their participation in this study. Their official national ranking were gathered 2016-04-12 from Swedish TT federation (Svenska Bordtennisförbundet, 2016). The trainers at SCOS, Aspero Idrottsgymnasium and HBTK where asked if they could recommend any to participate in the study. Subjects which matched the inclusion criteria’s where then asked and given information about the tests, from the test leader, both written and verbal. Their written consent was gathered before any tests was performed. Subjects under age of 18 needed their parent, guardian or TT trainer’s approval in order to be allowed to participate in the study.

Test sessions

Three test sessions was completed by the table tennis players during a period of eight weeks, Cooper’s test and Critf test at two different speeds, 48b/m and 56b/m. Each test session was separated by at least 24 hours and approximately the same amount of rest between each session for all the subjects. The subjects were informed to wear a certain shoe for each test. As for the Cooper’s test the subjects should wear running shoes or shoes with the same characteristics as running shoes, and for the Critf test they should use the same shoes as when they are practicing TT. They were also informed to not perform or participate in any form of training within 24 hours’ prior the test sessions and that they were not allowed to intake any food, caffeine and nicotine within 3 hours’ prior the test sessions. A pilot-study was performed with a robot (STAG 989D Table Tennis Robot, Meerut, India) in order to see whether the test should be successful with that robot. During the pilot study it occurred some deficiencies about the robot’s reliability, therefore that robot was changed to a new robot (Butterfly, AMICUS Basic, Moers, Germany). A pilot-study was performed with the new robot, were the robot’s reliability showed to be better than with the first robot.
Cooper’s test 3000m

Test session one was the Cooper’s test performed on a treadmill (STARTRAC, E-TRx, Irvine, USA). Before the test a warm-up was completed, containing of five minutes jogging on the treadmill (Baechle & Earle, 2008) followed by an active rest with encouragement for dynamic stretching, since this was normally performed by the players during their TT warm-up routine. The dynamic stretch was not standardized, but consisted mostly of dynamic stretching for mm. quadriceps femoris, mm. hamstrings and mm. adductors. The starting speed was standardized at 8 km/h and then self-selected for the rest of the warm-up. The subject was informed to not exceed an intensity level of 10 at Borg RPE-scale (made to measure perceived rate of exertion with 6 as no exertion and 20 as maximum) (Borg & Kajser, 2006) during the warm-up. Before the Cooper’s test started all subjects were given the same instructions in form of completing the 3000m run in the shortest amount of time, and to give the test leader instruction to increase or decrease the speed with commands as faster respectively slower, no cheering was performed during the test. The standardized starting speed for the Cooper’s test was 10km/h, thereafter self-selected during the rest of the test. At subject’s command faster/slower the test leader changed the speed 1km/h or a specific amount (2, 3 or 4 km/h) for increase/decrease. In order to achieve more similar conditions as out-door performed Cooper’s test, the grade of the treadmill was set to 1% incline. According to Jones & Doust (1996) the VO₂ measured on treadmill with a 1% incline grade showed the highest correlation which was not significantly different to outdoor measurements of VO₂ (r=0.99). The data was collected in minutes and then transformed in to seconds, in order to compare the results with the other test.

Critical frequency test

Test session two and three was the Critf test, where test session two was performed on the speed of 48 balls/minute and test session three on 56 balls/minute. Balls were shot at two alternative points at the table, which made the ball land 30-40 cm on either side of the middle line and 50-60 cm from the net (figure 1). This to simulate a real opponent (Zagatto, Papoti, & Gobatto, 2008; Zagatto & Gobatto, 2012).
Before each test session there was a warm-up, which was performed with the mechanical ball thrower (Butterfly, AMICUS Basic, Moers, Germany) in the same pattern as the Critf test, but at a speed of 35 balls/minute and for five minutes, followed by a rest period of five minutes before the actual test began (Zagatto, Papoti, & Gobatto, 2008a; Zagatto & Gobatto, 2012). The brand for the balls used was STIGA Optimum (Tranås, Sweden), a three starred ball, approved by ITTF for usage in international matches. The instructions before the test started was that the subject should return each ball with an offensive forehand stroke and continue the test until complete exhaustion, or until a consecutive error of four. An error occurred when the subject missed the ball, the return missed the table, returned the ball in the net or the ball hit the net behind the table. All subjects did get the same information before the test started, no cheering were allowed during any of the tests. Critf test has not been tested for reliability but has previously been used and recommended by Zagatto. The data was collected in minutes and then transformed in to seconds, in order to compare with the other test.
Ranking system

Since the ranking system was updated the first Monday in each month, the subjects data was gathered Monday fourth of april. Each subject was searched for in the ranking list, their placement was noted. Since the players was ranked from 20 – 2700 in this study, they were all given a number depending on their placement in the group. The one person best on the ranking list in the group, was given number one and the person who’s placement was the lowest were given number 14. This was also done in order to not be able to track ranking placement to the actual person, as a manner of secrecy.

Statistical analysis

The collected data was analyzed with Statistical package for the Social Sciences (SPSS) v.25 (SPSS Inc., Chicago, IL., USA). In order to keep the subjects’ secrecy, their official ranking was changed to group ranking from 1-14, based on their official ranking, this made the data ordinal and non-parametric statistics was used. Anthropometry data for age, length, weight and ranking of the subjects are presented in total for the group, and divided in male and female. The data are presented as median and minimum respectively maximum. The results for Critf and Cooper’s test are presented in seconds (s). Spearman’s correlation coefficient (r) was used to study the strength of the correlation between subject’s group ranking, based on their national ranking and the Cooper’s test and the Critf test, with an r-value of: <0.4 as weak, 0.4 – 0.6 as moderate and 0.6> as strong (Thomas, Nelson, & Silverman, 2011).

Ethical and social consideration

This study follows the guidelines according to the declaration of Helsinki (World Medical Association, 2013; Vetenskapsrådet, 2002). All subjects who were asked for their participation in the study, was informed about their rights and purpose of the study. Information letter regarding tests and ethical and social considerations and a written consent was handed out to each subject before participating in any tests (appendix 1 and 2). Subjects under age of 18, needed parental, guardian or TT trainers written approval for participating in this study. The subjects were informed about their rights to withdraw from the study without getting asked about a reason and without any consequences. The subjects were informed about how their personal information was handed due to safety and secrecy. All data was stored and organized
in Excel (Microsoft Excel 2016). All subjects were given an identification number, so that it was impossible to track result and personal information to subjects. In order to keep secrecy all data was saved on a USB memory stick, which after the study was completed, were handed in to the University of Halmstad. The social considerations of this study, was to give the Swedish Olympic committee a complement to Cooper’s test in form of a sport specific aerobic endurance test for table tennis players. It is also of the trainers’ interest in different table tennis clubs to have a more sport specific test for aerobic endurance for their players.

Results

Twenty-five subjects were invited for participation in this study, of those, seventeen subjects, both males (n=10) and females (n=7) agreed to participate. Fourteen subjects, males (n=10) and females (n=4), completed all three tests, the three subjects who chose to not fulfill their participation, did not give any further information about their reason to withdraw from this study. The anthropometry data of age, length, weight and ranking, is described in Table 1, in median, minimum and maximum value in total group and divided by sex. The subjects who participated in the study were of a different skill level in TT and ranked between 20-2700 in Sweden.

Table 1 - Descriptive statistics of subjects age, length, weight and ranking. Describing median and minimum and max values in total for group and divided by sex (n=14).

<table>
<thead>
<tr>
<th>Descriptive data</th>
<th>Total value</th>
<th>Total value for male</th>
<th>Total value for female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Min-Max</td>
<td>Median</td>
</tr>
<tr>
<td>Age</td>
<td>17</td>
<td>14-27</td>
<td>18</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>175</td>
<td>160-187</td>
<td>181</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>70</td>
<td>50-90</td>
<td>72</td>
</tr>
<tr>
<td>Ranking</td>
<td>859</td>
<td>29-2656</td>
<td>277</td>
</tr>
</tbody>
</table>

Information regarding Table 1:
cm = centimeters
kg = kilograms
The Descriptive results of Cooper’s test and Critf test (48b/m and 56b/m) are shown in Table 2.

Table 2 - Results for Cooper's test and Critf test (48balls/minute and 56balls/minute). Results are expressed in seconds (s) and presented as median, minimum and maximum, in total for group and divided by sex (n=14).

<table>
<thead>
<tr>
<th>Test results</th>
<th>Total value (N=14)</th>
<th>Total value for male (N=10)</th>
<th>Total value for female (N=4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Min-Max</td>
<td>Median</td>
</tr>
<tr>
<td>Cooper's test over 3000m (s)</td>
<td>823</td>
<td>652-973</td>
<td>760,5</td>
</tr>
<tr>
<td>Critf 48 balls/minute (s)</td>
<td>247</td>
<td>65-948</td>
<td>280</td>
</tr>
<tr>
<td>Critf 58 balls/minute (s)</td>
<td>162</td>
<td>49-288</td>
<td>162</td>
</tr>
</tbody>
</table>

Information regarding Table 2:
S= seconds

A strong correlation was found between Cooper’s test and subjects group ranking based on their national ranking ($r=0.600$ and $r^2=0.360$, $p=0.023$) (Fig.2).

Figure 2 - Diagram describing Spearman’s correlation between the subjects’ result on Cooper's test in seconds and their group ranking based on their national ranking (n=14).
A weak non-significant correlation was found between Critf test at 48 balls/minute and their group ranking based on their national ranking ($r=-0.341$ and $r^2=0.116$, $p=0.233$) (Fig.3).

Figure 3 - Diagram describing Spearman’s correlation between the subjects’ result on Critf test at 48 balls/minute in seconds and their group ranking based on their national ranking ($n=14$).

A weak non-significant correlation was found between Critf test at 56 balls/minute and their group ranking based on their national ranking ($r=0.022$ and $r^2=0.0005$, $p=0.940$) (Fig.4).

Figure 4 - Diagram describing Spearman's correlation between the subjects result on Critf test at 56 balls/minute in seconds and their group ranking based on their national ranking ($n=14$).
Discussion

According to Kondrič, Zagatto, & Sekulić (2013) and Kondrič, Furjan-Mandić, Kondrič, & Gabaglio (2010), TT as a sport, demands a combination of both aerobic and anaerobic endurance. The aerobic endurance is important for TT players, since it is a part of regenerating ATP to use during the intense periods, but also to help the player to stay focused and active during competitions and matches. As the correlation was stronger between Cooper’s test and subjects group ranking, based on their national ranking, than between the more sport-specific test in TT players when comparing to the subjects group ranking, the hypothesis for this study was false.

Results discussion

Cooper’s test

The Cooper’s test is frequently used by the Swedish Olympic Committee for many different sports within the Olympics (Svenska Olympiska Kommittén, 2016). Regarding this, there have been no earlier studies, to the author’s knowledge, which compares player performance in TT players with their results on Cooper’s test. The results in this study showed a strong correlation between the subjects results on Cooper’s test and their group ranking based on their national ranking. The correlation is based on the ranking for both males and females, since their ranking system is constructed in this way (Svenska Bordtennisförbundet, 2015). This result indicates that the Cooper’s test can be a good test for measuring aerobic endurance in TT players, even though it is not very sport specific, from a TT perspective. A similar result to the present study was found in a study from Ziemann, Śledziewska, Grzywacz, Gibson, & Wierzba (2011) which compared Cooper’s test and international ranking for female tennis players. A strong significant correlation was found between the subjects international ranking and Cooper’s test. Studies which have compared Cooper’s test with other aerobic endurance tests such as a treadmill test with measurements of VO_{2max} (Cooper, 1970) have showed a strong correlation between distance covered during the 12-minute run and measured VO_{2max} and Bandyopadhyay (2015) did a similar study with the same measurements and showed a strong correlation between distance covered in Cooper’s test and VO_{2max} measurements. This means that the Cooper’s test is a valid submaximal test of aerobic capacity. The reason for why there is a strong correlation between Cooper’s test and subjects group ranking, is probably because a player who is higher ranked, seems to have a higher VO_{2max}, which could be due to a higher amount of training hours.
Many of the subjects had not been running for a while. This might have affected their motivation for performing the Cooper’s test, which might have affected their result. Since they could have been thinking that I can not perform my very best and therefore I do not have to push me that hard. The fact of that they had not been running recently may have influenced the result, based on running economy, running technique and pace tempo (Cooper, 1970).

Critf test
The Critf test which was founded by Zagatto, Papoti, & Gobatto (2008b) in order to provide a more sport specific TT test for aerobic and anaerobic endurance. In the present study a weak correlation between Critf test at 48 respectively 56 balls/minute was found. In earlier studies the result of Critf test have not been compared with subjects national or international ranking, but a study from Zagatto A. M., Papoti, dos Reis, & Gobatto (2011) compared the results from Critf test with subjects group ranking. The group ranking was created with a group tournament where the winner of the tournament was ranked as number one and the loser was ranked as number 11. They found that there was no significant correlation between the Critf test and the group ranking. Some studies have been comparing Critf with other aerobic and anaerobic endurance test such as lactate minimum test, in which a weak correlation was found between results from Critf and lactate minimum test (Zagatto, Papoti, & Gobatto, 2008a) in another study from the same authors, a strong significant correlation was found between Critf and the lactate minimum test (Zagatto, Papoti, & Gobatto, 2008b). Incremental test, in which a strong significant correlation was found between results from Critf and the incremental test (Zagatto, Papoti, & Gobatto, 2008b). VO2max measurements, in which they found a strong significant correlation between Critf and VO2max measurements (Zagatto, Miranda, & Gobatto, 2011). The reason for why the result in the present study turned out the way it did, could be due to the lower capacity of the players, and that it is not suitable for players of a lower capacity. It could also be due to the fact that the test can not be used as a predictor of player performance when ranking is a dependent factor. Regarding that the Critf test could not be used as a predictor of player performance, it could be used for aerobic endurance training. In order to strengthen the sport specific endurance amongst TT players, as a complement to other aerobic endurance training. This is also confirmed by Zagatto, Miranda, & Gobatto (2011) that the Critf might not be a test for evaluating player performance, but the test is recommended to be a part of their TT training routine, in order to strengthen the TT specific aerobic endurance. Since the test simulates movement pattern similiar to the movement pattern performed during matches.
Some things which have been noticed during the implementation of this study, was that some of the players had a different performance-effort during the two tests of Critf, which could have affected the result. During one of the test their performance-effort was absolute maximum and not the same performance-effort was seen during the other test. Another thing which could have affected the result, was that some of the players changed their playing profile from offensive to more defensive during the tests, in order to accomplish a higher time during the tests.

The strong correlation between Cooper’s test and subjects group ranking was found to be stronger than the weak correlation which was found between Critf test at 48 respectively 56 balls/minute and subjects group ranking. This result indicates that the Cooper’s test most likely pictures the aerobic capacity in an adequate way, even though it can not be described as sport specific. Thus, the Cooper’s test can be used to understand a player’s actual performance in TT.

Discussion of methods

Participants

The subjects in this study had a big spread in the ranking list, it differed about 2600 placements from the highest ranked to the lowest ranked in the group. When Zagatto, Papoti, & Gobatto (2008b) did the validity study of the Critf test, their participants were all male, this means that the Critf test might not be adapted for female players. In the present study the subjects was both male and female. Regarding the aspect that in the present study both male and females was tested, it might have influenced the result since males and females differ in anatomy and might therefore differ in physical capacity. In a review from Joyner (1993) which found differences in running performance regarding time during 10.000m races and marathon races, were the time differed between males and females. Males had a faster performance time during both distances. Joyner mentioned that this might be due to differences in anatomy of sexes and therefore differences in physical performance between sexes.

Cooper’s test

In the present study, the Cooper’s test was performed on a treadmill. Since none of the subjects were familiar with running Cooper’s test on a treadmill, this might have affected their effort and capacity. In order to prevent the possibility of underperformance with future studies, is to accomplish the Cooper’s test on a running track, since most persons are more used to that test.
Performing Cooper’s test on a running track could produce both positive and negative effects. Subjects who motivates by competition could have a higher motivation and effort when completing the test on a running track, since it is performed with others. But for subjects who demotivates by competition this could have the opposite impact.

Critf test
The Critf test was performed at two different speeds, 48 respectively 56 balls/minute. In studies from Zagatto, Papoti, & Gobatto (2008b), Zagatto, Papoti, & Gobatto (2008a) and Zagatto, Miranda, & Gobatto (2011) they have tested their players on four different speeds, 48, 56, 65 and 72 balls/minute. Their group of subjects were all male players. The fact that this test have only been tested on males is a weakness for the result in the present study, since the test have not been validated for females, which means that it may not be adaptable for females.

Player profile could have an influence on how the players are returning each ball when performing the test. A player can approach each shot offensive or in a more defensive way, even though the strokes should be offensive forehand strokes. Which means that a player with a more defensive approach would hit each ball in a more economic way, regarding oxygen consumption. This was an aspect that the TT trainer indicated. Another aspect with this method is that it is only testing their aerobic endurance when the subjects are hitting forehand strokes, which means that a player with an insufficient forehand stroke could have a more poorly performance during this test in comparison to a player with a better forehand stroke. This aspect is discussed by Zagatto, Papoti, & Gobatto (2008b) where they define it as a limitation with the test. Since a match contains forehand, backhand and defensive strokes, and that they may influence the physiological parameters in a match. This was also noted and discussed with the TT trainer who watched some of the subjects perform the Critf tests during the present study. The TT trainer argued for that a test which analyzed both backhand and forehand strokes was needed, since a match contains more types of strokes and not only forehand strokes.

Regarding that a player’s performance-effort differed between the Critf test at 48 respectively 56 balls/minute, was seen only through a visual overview. In future studies, a method which measures heart rate could be useful in order to determine that the performance-effort does not differ to much during the tests.
The material each player has, can differ a lot due to different brands and thickness, they could also have one side of pimple rubber which acts to nullify spin, with this type of material they do not need to put spin to the ball in the test and therefore their performance might be better than a person with normal rubber on his or her racket, since less energy is used, regarding oxygen consumption. Standardization was done regarding TT table and TT balls. No standardization was made due to which material each player used during the test. A factor for not standardize which material each player used, was that it could affect their result during the test. Another factor for not standardizing the material, was that it would have gotten too expensive in order to standardize the material, since it is a high cost and a high tear to the material during this kind of test.

Conclusion

According to this study, the results showed a strong correlation between Cooper’s test and subjects group ranking, based on their national ranking. This means, that in table tennis players ranked from 20-2700 in Sweden, the Cooper’s test could be used, in order to evaluate player performance. However, the group is relatively small and the coefficient of determination tells us that it is only in some of the cases. Results of the Critf test showed a weak non-significant correlation with subjects group ranking and could therefore not be recommended in evaluating player performance. Future research is needed to evaluate the Critf test in this area, on a more homogenous group concerning the ranking list in Sweden.
References


http://iof1.idrottonline.se/ImageVaultFiles/id_13724/cf_74/T-vlingsregler.PDF

http://iof1.idrottonline.se/SvenskaBordtennisforbundet/Tavling/Ranking/Sverigeranking/

http://www.fysprofilen.se/sv/Utmanardokument/Testbeskrivningar_Fysprofilen_Utmanare%20131216.pdf


Appendices

Appendix 1. Information form which was handed out to each subject.

Information vid deltagande i studien

Hej!

Jag heter Pontus, läser tredje och sista året på Biomedicin – inriktning fysisk träning på Högskolan i Halmstad. Jag gör just nu mitt examensarbete och undrar om du vill delta i min studie där en undersökning av relevansen att använda ett sportspecifikt test för mätning av den aerobiska uthålligheten i jämförelse med nuvarande Cooper’s test.


Syftet med testet är att jämföra resultaten från Critical Frequency test med resultatet från Cooper’s test för att se vilket test som korrelerar bäst med den nationella rankingen som du som spelare har.

Förfrågan om deltagande


Tillvägagångssätt

Studien kommer innehålla fem testtillfällen. Under det första testtillfället kommer du att utföra

Ditt deltagande i studien medför inga risker som inte förekommer under dina vanliga träningspass.

**Frivilligt deltagande**

Du som testperson har rätt att avbryta testet när som helst utan att ange orsak. Om så önskas kommer då redan insamlad data att förstöras.

**Sekretess**


Vänligen,
Pontus Sparf

**Ansvariga**

Ansvariga för studien är:
Pontus Sparf
Biomedicin – inriktning fysisk träning
Högskolan Halmstad
076-863 14 65
pontus@sparf.info

Handledare:
Emma Haglund, universitetslektor vid Högskolan i Halmstad
Appendix 2. Content form which was signed by each subject.
Samtycke till deltagande i forskningsstudie

Nedan ger du ditt samtycke att delta i den studien som undersöker relevansen för användandet av ett sportspecifikt test för att mäta aerobisk uthållighet istället för Cooper’s test eller som ett komplement. Läs igenom informationen noga och ge ditt medgivande genom att signera ditt namn nederst på sidan.

Jag medgiver att jag:

- Har tagit del av informationen kring studien och förstår vad den innebär.

- Har fått ställa de frågor jag önskar och vet vem som är ansvarig huvudman om jag har fler frågor.

- Deltar frivilligt i studien och förstår varför jag har blivit tillfrågad.

- Vet att jag när som helst kan avbryta mitt deltagande i studien utan att ange orsak.

Jag intygar att jag har läst det informerade samtycket och tagit del av informationen kring studien. Jag förstår vad deltagande i studien innebär och ställer upp frivilligt.

Ort och datum___________________________________________________________

Namn________________________________________ Underskrift_________________ 

Ort och datum____________________________________________________________

Underskrift vårdnadshavare________________________________________